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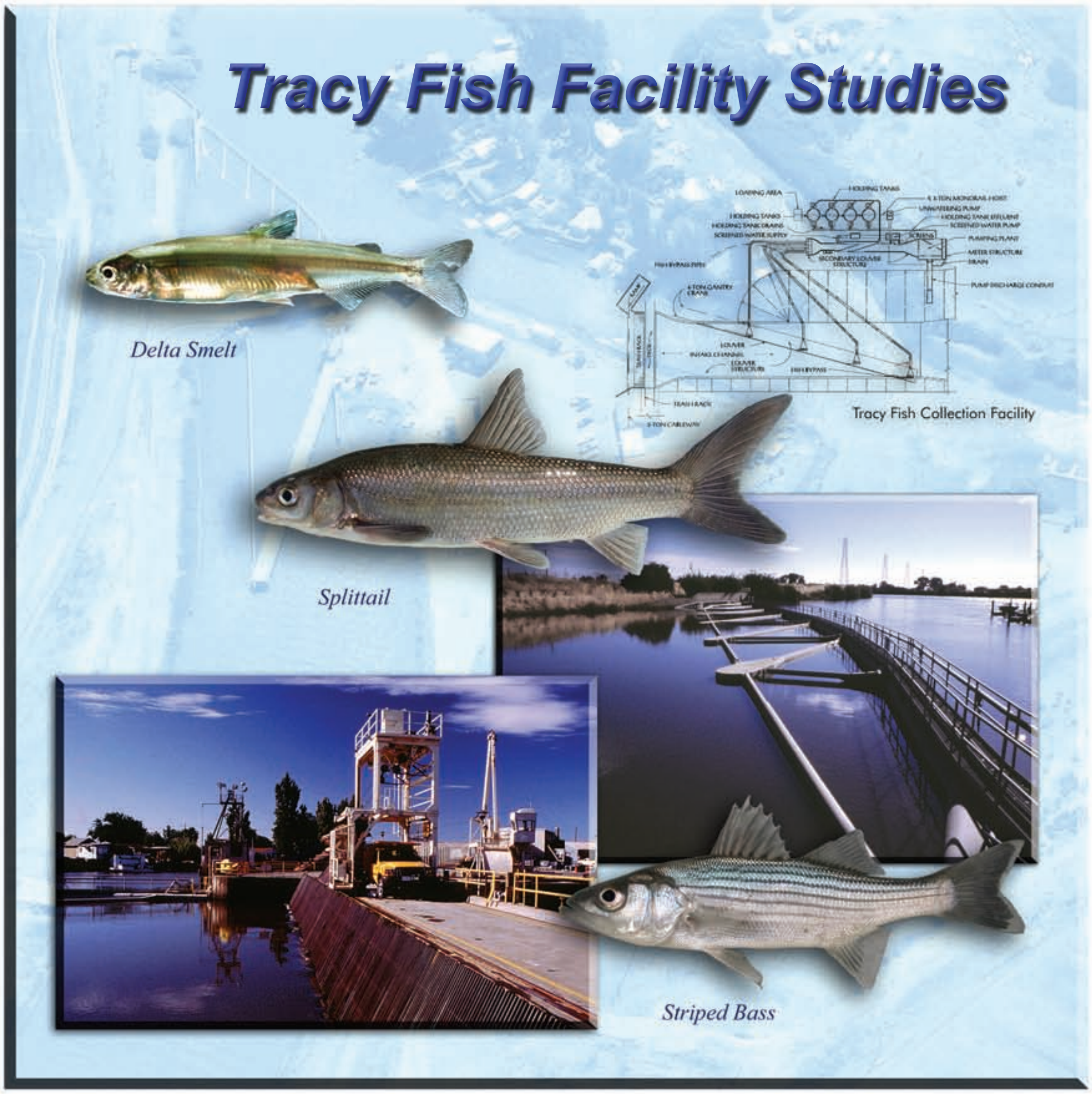

Evaluation of Fish Holding at the Tracy Fish Collection Facility

Volume 39

U.S. Department of the Interior
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14. ABSTRACT
The U.S. Department of the Interior, Bureau of Reclamation's Tracy Fish Collection Facility in central California was designed to divert, collect, hold, and return salvaged fish to the Sacramento-San Joaquin Delta. Fish diverted from entry into the Delta Mendota Canal are collected and held in large circular recessed holding tanks for up to 24 hours (h) awaiting transport. We conducted experiments to determine if holding conditions were damaging collected fish. Sacramento blackfish, *Orthodon microlepidotus*; splittail, *Pogonichthyes macrolepidotus*; threadfin shad, *Dorosoma petenense*; American shad, *Alosa sapidissima*; and steelhead, *Onchorhynchus mykiss*, were held with wild entrainment for varying time periods, and then examined for scale loss. Some fish were held for 24-h survival assessment. We observed no open lacerations or missing body parts on the experimental fish. Both holding and fish lift/transfer processes caused some scale loss (up to 58.3 percent of the fish); however, most fish (92.2 percent) showed less than 5 percent loss. Twenty-four-h survival was high for all species except one test with American Shad. We found no statistical relationship between scale loss and holding time, debris load, tank velocity, and density of wild entrained fish.

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Tracy Fish Facility Studies
California

Evaluation of Fish Holding at the Tracy Fish Collection Facility

Volume 39

by

Cathy Karp[1] and Judy Lyons[1]

January 2008

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Tracy Fish Facility Improvement Program

Ron Silva, Manager

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EXECUTIVE SUMMARY

The U.S. Department of the Interior, Bureau of Reclamation's Tracy Fish Collection Facility in central California was designed to divert, collect, hold, and return salvaged fish to the Sacramento-San Joaquin River Delta (Delta). Fish diverted from entrainment into the Delta Mendota Canal are collected and held in large circular holding tanks for up to 24 hours awaiting transport and release to the Delta. We conducted experiments to determine if current holding conditions are damaging fish because of injuries noted in the summer salvage when river temperatures are high, and in the fall/early winter salvage when debris loads are high. We saw no evidence of open lacerations or recently killed fish. We found that both holding and fish lift/transfer processes caused minimal external damage (most fish, 92.2 percent, exhibited < 5 percent scale loss). Physical variables (including debris load, tank velocities, and wild fish densities) that were expected to be damaging were not significantly correlated with scale loss. It is possible however, that pre-experimental scale loss was masking experimentally induced scale damage. Future research with a new fish transfer bucket should allow for better separation of holding and fish transfer processes, and possible detection of other portions of the salvage process in need of improvement.

INTRODUCTION

The U.S. Department of the Interior, Bureau of Reclamation (Reclamation) is evaluating and improving the current fish salvage process at the Tracy Fish Collection Facility (TFCF) near Tracy, California. This facility is located on the Old River branch of the San Joaquin River and diverts entrained fish from exported Central Valley Project flows (figure 1). The fish salvage operation has four major components: (1) fish are diverted and entrained into large holding tanks, (2) held for varying periods in a swirling flow, (3) removed and transported, and (4) released back to the San Joaquin-Sacramento River Delta (Delta). The holding and fish lift/transfer systems were designed in the 1950s for fish between 35 and 50-millimeter (mm) total length (Bates *et al.*, 1960), when vegetative debris loads were much lower than today. The current system annually handles millions of fish comprising over 50 species. This study was an evaluation of the holding component of the fish salvage process at the TFCF, and complements ongoing studies of the Collection, Handling, Transport, and Release Program at the Skinner Delta Fish Protective Facility (Morinaka, 2006).

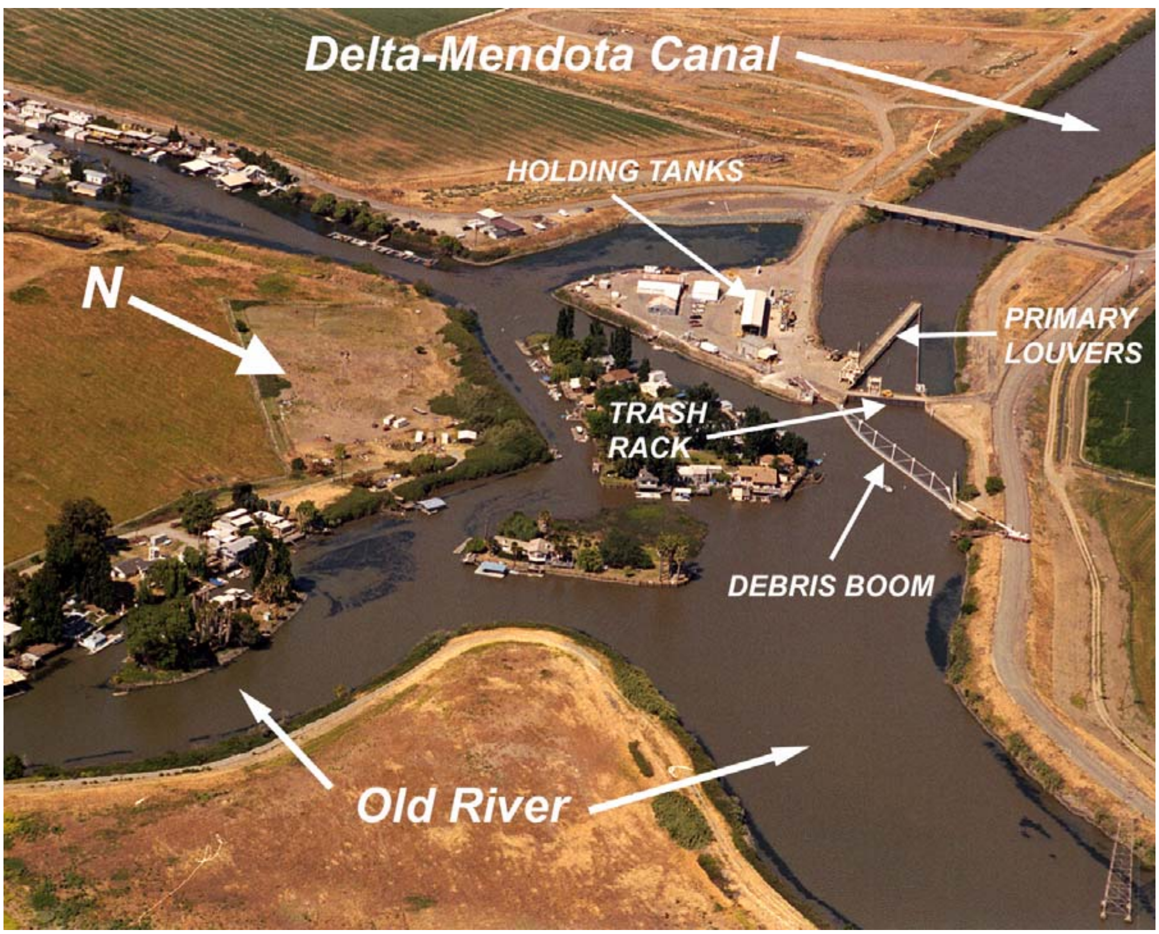


FIGURE 1.—Tracy Fish Collection Facility, Old River Branch of the San Joaquin River, California.

There are four recessed circular collection/holding tanks at the TFCF. Fish and other entrained material (e.g., vegetative debris, human litter, sand, and clamshells) continuously enter one holding tank at a time through a 50.8-centimeter (cm) (20-inch [in]) pipe at the bottom (figure 2). Water passes through a centered woven-wire screen that is a cylinder 2.4 meters (m) (8 feet [ft]) in diameter, 4.6 m (15 ft) high, with 0.3-cm square mesh openings. Most fish and entrained material are blocked by the screen and swirl counterclockwise about the tank with the incoming flows. At the end of a collection, water is drained through the screen, the screen is lifted and fish and materials are flushed into the fish transfer bucket (1,900 liter [L] [500 gallon (gal)] with a 22.9 cm [9 in] outlet opening) for removal (figure 3). Once lifted from the recessed tank to ground level, entrained fish are then transferred to a 7,571-L (2,000-gal) transport truck. The collection tanks are 6.1 m (20 ft) wide and 4.57 m (15 ft) deep with a conical bottom to accommodate the fish lift bucket. Tank capacity is 132,000 L (35,000 gal) with incoming flows ranging from 0.19 – 0.31 cubic meters per second (m^3/s) (7 – 11 cubic feet per second [ft^3/s]); (Bates *et al.*, 1960). Water depth and velocity fluctuates throughout the holding period depending on tide stage and the number and type of pumps (including diversion and salvage pumps) in use. The tanks are concrete with epoxy-coated sides and bottom to reduce fish injury from contact with the concrete. Fish are collected and held for up to 24 hours (h) awaiting transport and release. Holding times vary seasonally, generally, entrained fish are held for 8 h in the spring when Delta smelt, *Hypomesus transpacificus*, may be present, 12 h in the winter and spring when Chinook salmon, *Oncorhynchus tshawytscha*, may be present, or 24 h the remainder of the year unless fish densities demand more frequent release hauls (Bates *et al.*, 1960).

The holding tank environment is a constantly changing system for diverted South Delta fish awaiting transport and release. Water temperatures, salinity (and other water quality parameters), debris (biological and other), and fish numbers and types change continuously with tidal stage, South Delta export pumping, and time of year. However, little is known about effects of confinement for long periods with fluctuating water quality, velocities, entrained debris, and wild fish density and species, predation, and tank structure (see Portz *et al.*, 2005 for summary of short-term holding effects on freshwater fishes). The objective of this study was to investigate the extent of holding-induced physical injury at the TFCF. Specifically, we evaluated scale loss and predation in fish exposed to the holding and transfer processes. The skin, scale, and mucus complex of fish is both protective and involved in many functions necessary to life (Lagler *et al.*, 1977). However, damage to this system may cause stress, disease, and death (Gadomski *et al.*, 1994; Kostecki *et al.*, 1987).

FIGURE 2.—Top and inside view of the recessed holding tank, TFCF, California.

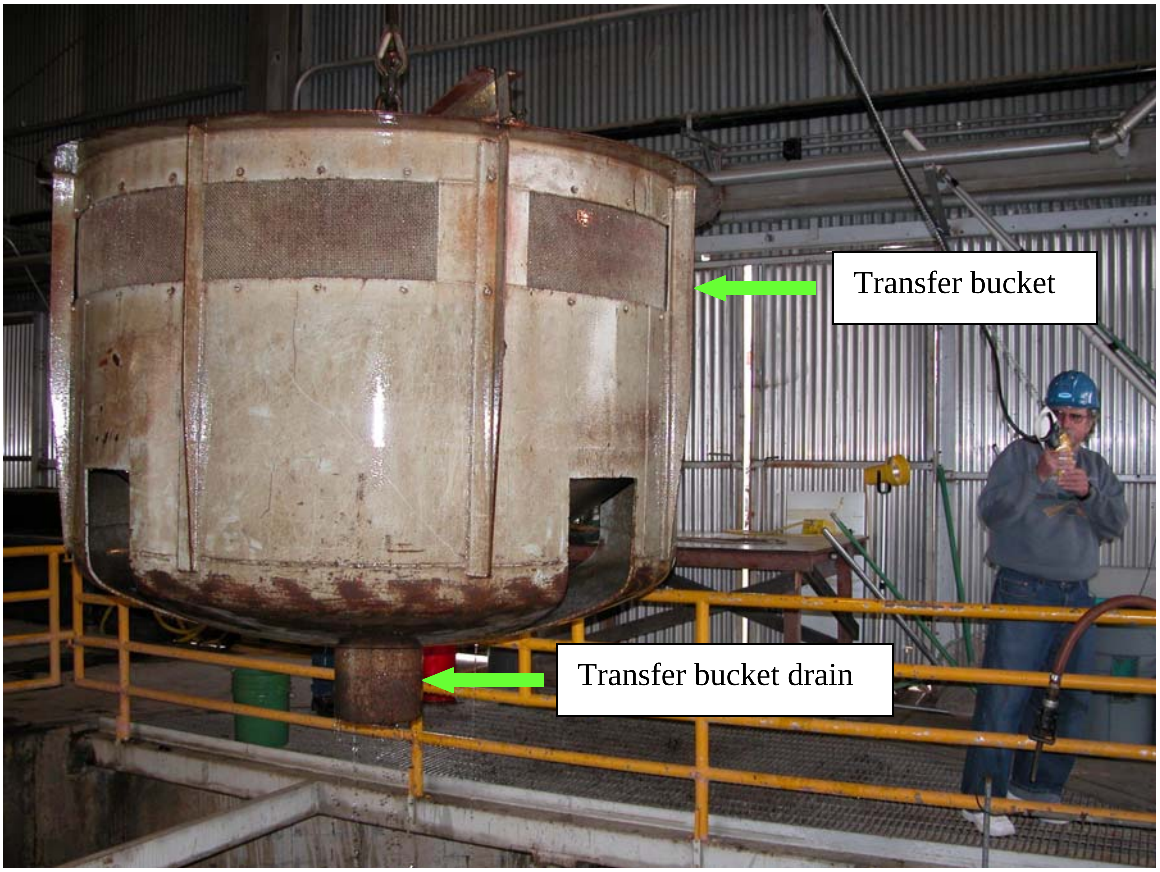


FIGURE 3.—Fish transfer bucket used to remove fish from the recessed holding tank, TFCF, California.

METHODOLOGY

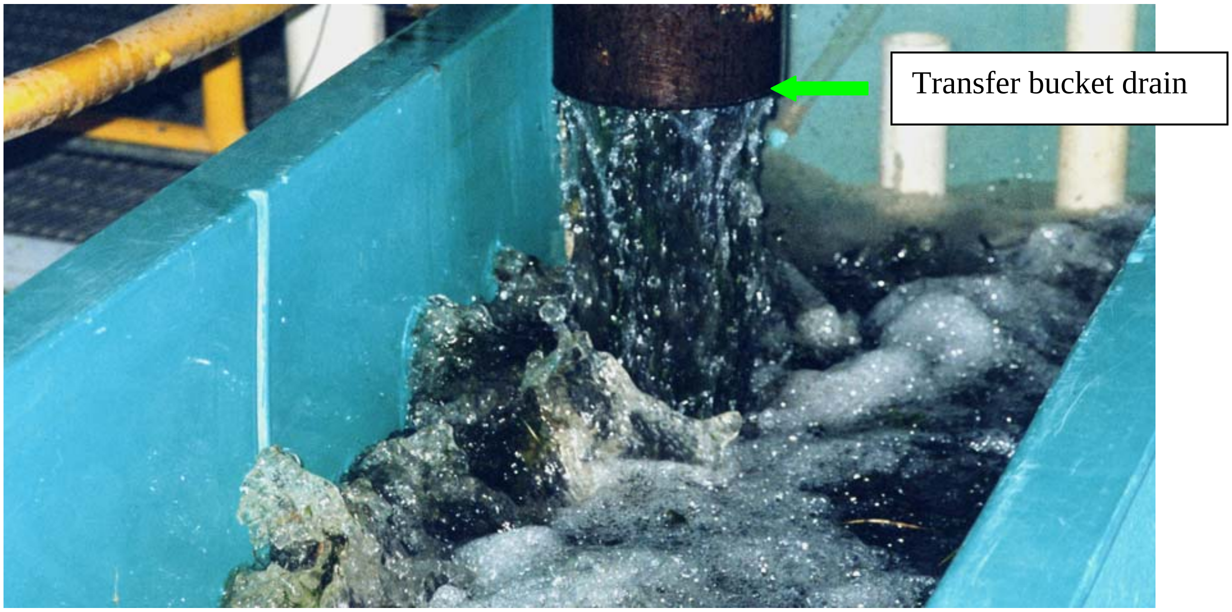
Fish release-recovery experiments were used and all fish were acclimated to ambient Delta water conditions for 7 days prior to use (fish were held in 19 ^{o}C aerated well water, and either cooled or warmed 1 week prior to testing in mixed well and Delta water to match the ambient Delta water temperature). There were two types of experiments: (1) transfer only experiments: fish recovered using the 1,900-L (500-gal) lift bucket without exposure to flow or wild entrainment and (2) holding/transfer experiments: fish held (swirled) with the wild entrainment under varying velocities for the experimental time, then recovered and transferred. In both, a group of fish (c.a. 50) was transported to the holding tank area in a 76-L (20-gal) plastic tub. The holding tank was filled either by opening the inlet pipe or by backfilling through the drain system (used exclusively after the first year). Five fish were randomly captured (water-to-water transfer) and anesthetized with tricaine methane sulphonate (MS-222; 50 milligrams per liter [mg/L]) for external examination. The 76-L tub containing the remaining experimental fish was then lowered into the backfilled water and fish released (figure 4). In the transfer-only experiments, fish were immediately recovered using the lift/transfer bucket without exposure to incoming flow. In the holding/transfer experiments, the inlet valve was opened to allow incoming flow and the holding experiment (swirl) began. At the end of the experimental period (1, 2, 4, 8, 12, or 24 h), flow was diverted to another collection tank and the test tank was drained. Fish and entrained material were concentrated in the sill around the center screen and flushed into the fish lift bucket for recovery (figure 5). We then moved this bucket above a 1,900-L (500-gal) rectangular sorting tank and the contents were released (figure 6). Velocity measurements were taken throughout the swirl using a Marsh-McBirney flow meter. Measurements were taken near the center screen, in the middle of the tank, and near the outside wall, about 61 cm (2 ft) from the surface (water depth varied with tide stage). All experiments were conducted in the same tank. There were baffles in the tank to slow incoming flow and a ladder extended to the bottom for access. All fish were recovered similarly using the lift/transfer bucket and sorting tank. Fish were recovered from the sorting tank using water-to-water transfer to the 76-L tub, and from these, five fish were randomly selected for external examination (see description in following paragraph). The remainder was held in Delta water to assess survival at 24 h (post experimental holding was limited to 24 h because of insufficient holding capability). We also assumed internal damage resulting from the experiment would show externally in 24 h. Numbers and species of wild fishes and a wet debris weight were determined for each holding/transfer experiment. Debris was collected using hand rakes and aquarium nets, and weighed to the nearest kg. Some debris was removed from the holding tank using pitchforks during highest debris loads to reduce abrasions that may occur in the transfer process (see figure 5). This debris was added to the total weight for the experiment. All possible predatory fish stomachs were examined for predation of experimental fish. All experimental fish were measured to the nearest mm as fork length (FL), following the experiment to avoid additional pre-experimental handling.

The pre and post external examination was adapted from Goede and Barton (1990), Adams *et al.*, (1993), and McNabb *et al.*, (2003). Fish taken for the external damage assessment were held in a 50 mg/l solution of MS-222. Each fish was examined under Baush & Lomb StereoZoom and Leica MZ 7 microscopes for scale loss, external bruising, and hemorrhaging. Left and right sides of each fish were divided into three zones (figure 7) and the percent scale loss per zone was estimated. The total percent scale loss/fish was then determined and averaged for the trial.

Experimental fish species (figure 8) included splittail, *Pogonichthyes macrolepidotus*, (66 – 193 mm FL); Sacramento blackfish, *Orthodon microlepidotus*, (37 – 256 mm FL); threadfin shad, *Dorosoma petenens*, (45 – 180 mm FL); American shad, *Alosa sapidissima*, (117 – 180 mm FL); and steelhead, *Onchorhynchus mykiss*, (132 – 297 mm FL). Threadfin and American shad and splittail were wild-caught fish acclimated to TFCF conditions. Sacramento blackfish were obtained from the Professional Aquaculture Service, Chico, California. Hatchery steelhead were obtained from the Mokelumne River Hatchery, California. Experiments were begun using the two shad species, splittail, and steelhead. However, these fish required a unique mark to distinguish them from wild fish and we switched to Sacramento blackfish, as they were rare in the fish salvage at the TFCF and thus, did not require an additional marking procedure. Only one species was tested at a time.

FIGURE 4.—Experimental fish release into the holding tank, TFCF, California.

FIGURE 5.—Fish recovery after experimental holding under heavy debris fouling, TFCF, California.



(a)

(b)

FIGURE 6.—Fish release from the fish transfer bucket for sorting and examination, TFCF, California.
(a) Fish being released from the transfer bucket into sorting tank.
(b) Fish recovery using water to water transfer.

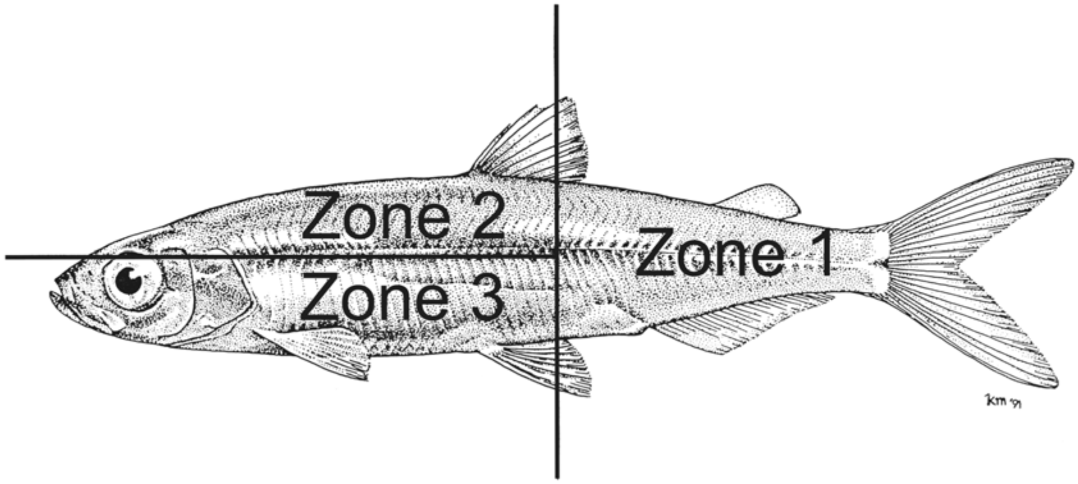


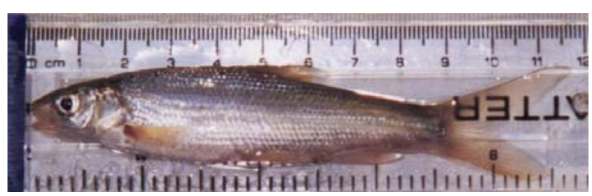
FIGURE 7.—Division of fish for external examination of scale loss, TFCF, California.

American shad

Steelhead

Threadfin shad

Sacramento blackfish



Splittail

FIGURE 8.—Fish species used in the holding tank experiments, TFCF, California.

Data Analyses

Neither control nor treatment damage assessment data were normally distributed, so we used nonparametric statistics (Statistix 8, Analytical Software, Hollander and Wolfe 1973). Wilcoxon signed rank test (one-tailed) was used to evaluate baseline scale condition within holding periods (hypothesis: there was no difference in percent scale loss between fish handled [*pre*] and those exposed to handling + transfer [*post*; time = 0 h; 22 experiments], and handling [*pre*] to handling + holding + transfer [*post*; time = 1, 2, 4, 8, 12, and 24 h; 42 experiments]). We then subtracted the *pre* level of scale loss (or baseline scale loss) from *post* levels for each paired trial to standardize the trials across a range of fish and holding conditions, and used Kruskal-Wallis to test the hypotheses: (1) there is no difference in scale loss between fish exposed to transfer only and those exposed to holding and transfer process, and (2) there is no difference in scale loss due to time in the holding tank. These tests were completed for Sacramento blackfish (N = 38: 14 transfer only experiments, 24 holding/transfer experiments) and threadfin shad (N = 17: 7 transfer only experiments, 10 holding/transfer experiments) only because of small paired sample sizes for the other species. Survival data and physical data (debris, velocities, and wild fish entrainment) were analyzed for all species combined. Pearson correlation analysis was used for all species combined to test for relationships between physical conditions (holding time, velocity, debris load, and wild fish density) and scale loss.

RESULTS AND DISCUSSION

A total of 2,744 fish were released in transfer only (N = 22) and holding/transfer (N = 42) experiments. Of these, 21.6 percent (215 transfer only fish, 378 holding/ transfer fish; table 1) were examined for scale loss, and the remainder held for 24 h survival. More than 75 percent of all examined fish (76.8 percent -*pre* or handling only, 85.1 percent -*post* or transfer only and holding/transfer) showed some external damage but none were observed with open lacerations or missing body parts. The type of damage we observed included scale loss (scales detached and underlying skin discolored), hemorrhaging (possibly from scales being dislodged but remaining attached), and bruising (presumably from contact with entrained vegetation or physical structure, figure 9). Background or pre-experimental scale loss averaged 1.0 percent (0 – 11.7 percent) of a fish's body compared to 1.4 percent for transfer only fish (0 – 14.2 percent) and 2.6 percent for holding/transfer fish (0 – 58.3 percent). Most fish (92.2 percent) exhibited less than 5 percent scale loss, but several threadfin shad and Sacramento blackfish lost more than 10 percent of their scales (table 2). Larger fish of all species appeared to have more scale loss than smaller fish, probably due to collision with debris or tank and bucket walls.

TABLE 1.—Summary of scale loss data (all species combined) holding experiments, TFCF, California, May 2000–June 2005

	Number of fish examined	Percent loss
Transfer only		
Pre	104	75.0 (N = 78)
Post	111	80.2 (N = 89)
Holding and transfer		
Pre	167	77.8 (N = 130)
Post	211	87.7 (N = 185)
Total	593	

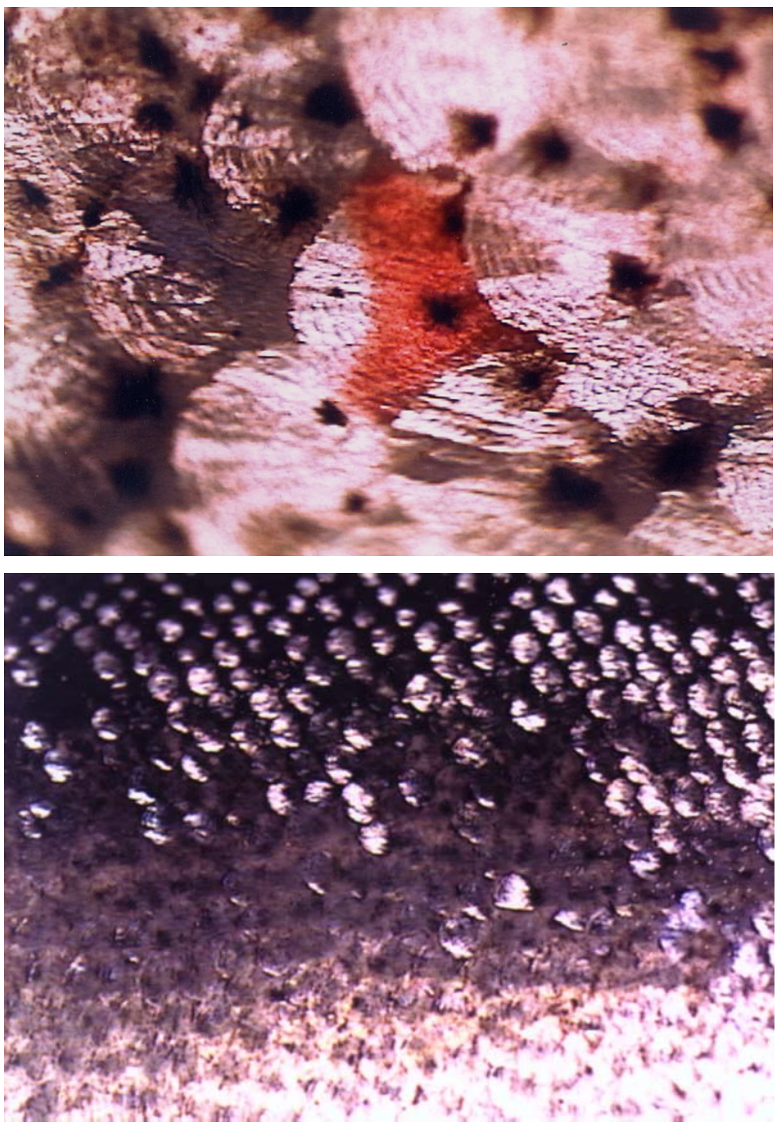


FIGURE 9.—Examples of scale damage observed in experimental fish, TFCF, California.

TABLE 2.—Summary of percent scale loss by species, holding experiments, TFCF, California, May 2000–June 2005.

Species	Number of Fish Examined	Mean Scale Loss (percent) Pre[1] (SD) (Range)	Post[2] (SD) (Range)
Sacramento blackfish	369	0.9 (1.1) (0 – 6.7)	2.0 (3.8) (0 – 23.3)
Threadfin shad	179	1.1 (0.9) (0 – 5.2)	3.9 (4.2) (0 – 58.3)
Splittail	21	4.0 (2.7) (0.3 – 11.7)	5.1 (2.5) (0.5 – 15)
American shad	13	2.0 (1.5) (0.5 – 4.3)	1.4 (0.5) (0.5 – 2.7)
Steelhead	11	2.0 (1.3) (0.7 – 5.8)	1.9 (1.3) (0.5 – 6)

[1] Handling only
[2] Handling, transfer and handling, holding, transfer

Comparison of *pre* and *post* levels of scale loss for Sacramento blackfish transfer only (N = 14, P = 0.0133) and holding/transfer (N = 24, P = 0.0251) experiments suggested some scale damage occurred (table 3). However, there was no statistical difference in scale loss between fish exposed to the fish transfer process only and those exposed to holding and transfer (N = 38, P = 0.7276). This suggests that Sacramento blackfish were more vulnerable to scale loss in the fish transfer process (from recessed holding tank to above ground transport) rather than the holding tank. Level of scale loss in threadfin shad was not statistically different between *pre* and *post* transfer only tests (N = 7, P = 0.31250) but was for all holding/transfer combined (N = 10, P = 0.0217; table 4). Scale loss in threadfin shad was also greater in the holding/transfer experiments compared to transfer only (N = 17, P = 0.0191), which suggests this species was more vulnerable to scale loss in the holding tank than Sacramento blackfish.

Twenty-four hour survival was high in all experiments except one 4 h with American shad (table 5). Only one predation incident (a 40 mm Sacramento blackfish was eaten by a 240-mm white catfish, *Ameiurus catus*) was observed. We observed 351 predatory size (> 100-mm [4-in]) striped bass, *Morone saxatilis*, and white catfish in the entrainment but presume conditions were unsuitable for predation to occur. Predation has been noted in the holding tanks during experimental releases in other experiments (Karp *et al.*, 1993, L. Hess, personal communication).

Holding tank velocities were as high as 1.4 m/sec (4.6 ft/s) but averaged 0.36 m/sec (1.2 ft/s, table 6). Velocities were highest during the initial stages of filling the tank and during low tide periods when tank depths were low (depth ranged to over 3.04 m [10 ft] depending on tidal stage). Entrained debris at the TFCF included a variety of material including clamshells, *Corbicula fluminea*, sand, peat fibers, aquatic vegetation (*Egeria* spp., *Eichornia crassipes*, and *Potamogeton* spp.), woody material, and human litter

TABLE 3.—Summary statistics of mean percent scale loss for Sacramento blackfish, holding studies, TFCF, California, May 2000–June 2005. P-values for Wilcoxon Signed Rank Test (one-tailed) of *pre* vs. *post* scale loss

Holding period (h)		Number experiments	Number fish pre/post	Scale Loss (percent)			
				Mean			
				Pre (SD)	Post (SD)	P-value	
0	transfer	14	67/70	1.0 (1.0)	1.8 (2.1)	0.0148	
1	holding/transfer	3	15/17	0.4 (0.2)	0.8 (0.1)	0.1250	P = 0.0299
2		5	26/30	0.4 (0.6)	0.7 (0.4)	0.2187	
4		3	16/17	1.3 (0.8)	0.9 (0.9)	0.6250	
8		6	28/31	0.6 (0.4)	4.6 (8.8)	0.0156	
12		6	21/25	1.3 (2.1)	1.4 (1.7)	0.2187	
24		1	2/4			—	

1.7 1.7

TABLE 4.—Summary statistics of mean percent scale loss for threadfin shad, holding studies, TFCF, California, May 2000–June 2005. P-values for Wilcoxon Signed Rank Test (one-tailed) of *pre* vs. *post* scale loss

Holding period (h)		Number experiments	Number fish pre/post	Scale Loss (percent)			
				Mean			
				Pre (SD)	Post (SD)	P-value	
0	transfer	7	34/38	0.7 (0.7)	1.2 (1.3)	0.3125	
1	holding/transfer	3	16/31	1.7 (1.2)	2.2 (1.3)	0.3750	P = 0.0217
2		2	10/13	1.3 (0)	7.0 (2.4)		
4		3	6/12	1.3 (0.9)	10.4 (5.0)	0.1250	
8		1	5/5	0.4	2.1		
12		1	5/4	2.4	4.4		

TABLE 5.—Summary of immediate and 24-hour survival following transfer only (0 h) and holding-transfer experiments (1, 2, 4, 8, 12, 24 h) TFCF, California, May 2000–June 2005.

Holding Period (h)	Species	Number of Experiments	Number of Fish (mortalities)	24-h Survival (%)
0	American shad	1	54 (0)	100
	Threadfin shad	7	172 (3)	98.3
	Sacramento blackfish	14	108 (0)	100
1	Threadfin shad	3	171 (0)	100
	Sacramento blackfish	3	17 (0)	100
	Splittail	2	76 (0)	100
2	Threadfin shad	2	118 (0)	100
	Sacramento blackfish	5	292 (0)	100
4	American shad	1	36 (8)	77.8
	Threadfin shad	3	160 (3)	98.1
	Sacramento blackfish	3	153 (0)	100
	Splittail	3	144 (3)	97.9
	Steelhead	2	102 (0)	100
8	Threadfin shad	1	74 (0)	100
	Sacramento blackfish	6	279 (0)	100
12	Threadfin shad	1	53 (6)	88.7
	Sacramento blackfish	6	424 (1)	99.8
24	Sacramento blackfish	1	40 (0)	100

TABLE 6.—Summary of holding tank velocities during the holding experiments, TFCF, California, May 2000–June 2005

		Holding tank velocities		
Holding period (h)	**Total number of readings**	**Mean m/s (ft/s)**	**Minimum m/s (ft/s)**	**Maximum m/s (ft/s)**
1	46	0.4 (1.4)	0.1 (0.3)	1.4 (4.6)
2	38	0.5 (1.6)	0.3 (0.98)	0.9 (3.0)
4	63	0.3 (1.0)	0.2 (0.6)	0.4 (1.4)
8	34	0.3 (1.1)	0.09 (0.3)	0.7 (2.5)
12	64	0.3 (1.1)	0.09 (0.3)	0.5 (1.6)
24	6	0.3 (1.0)	0.2 (0.8)	0.3 (1.1)

(figure 10). Debris load ranged from 0.2 – 15.0 kg/h (33 lbs/h; table 7) and was highest in the summer due to green plant material and in the spring when sand was moving with high flows (figure 11). Wild fish entrainment densities were also highly variable depending on time of year (up to 4,248 fish/h, table 8). Pearson correlation analysis of debris load, fish density, tank velocities and time with post- swirl scale damage (all species combined) suggested no statistical relationships ($P > 0.05$). However, we observed extensive scale loss in some fish during experiments with high debris load or high velocities (at low tide). We found no statistical relationship between scale loss and holding time for Sacramento blackfish (N = 38, P = 0.4421) or threadfin shad (N = 17, P = 0.1196).

FIGURE 10.—Variety of material entrained into the holding tank, TFCF, California.

TABLE 7.—Summary of entrained debris (kg) per h during the holding experiments, TFCF, California, May 2000–June 2005

		Debris		
Holding period (h)	**Number of experiments**	**Mean kg/h (lbs/h)**	**Minimum kg/h (lbs/h)**	**Maximum kg/h (lbs/h)**
1	8	1.6 (3.5)	0.3 (0.7)	3.1 (6.8)
2	[1]5	2.6 (5.7)	0.2 (0.4)	9.9 (22)
4	12	3.2 (7.1)	0.01 (0.02)	15 (33)
8	7	1.3 (2.9)	0.6 (1.3)	2.1 (4.6)
12	7	2.0 (4.4)	0.2 (0.4)	5.3 (12)
24	1	2.1 (4.6)	2.1 (4.6)	2.1 (4.6)

[1]Debris was not measured in two experiments.

FIGURE 11.—Heavy debris load (60 kg) collected during a 4-h experiment in July 2002, TFCF, California.

TABLE 8.—Summary of wild fish entrainment per h during the holding experiments, TFCF, California, May 2000–June 2005

		Wild fish entrainment (number fish/h)		
Holding period (h)	**Number of experiments**	**Mean**	**Minimum**	**Maximum**
1	8	28.5	7	42
2	7	50.9	12	128
4	12	554	12	1,218
8	7	788	1	4,248
12	7	236	4	1,301
24	1	4.1	4	4

CONCLUSIONS

Some external abrasions occurred in the holding/recovery environment but not nearly to the degree expected. We presumed we would see lacerations and missing body parts because such injuries are observed in some wild entrained fish (figure 12). However, the kinds of injuries observed in the experimental fish (e.g., scale damage and loss, external bruising, frayed fins, figure 9) were probably due to contact with debris, floor of the holding tank, and/or sides of the transfer bucket during the recovery process. Scale loss was generally minimal (92.2 percent of all examined fish had less than 5 percent loss) but appeared related to both the holding environment (for threadfin shad) and the fish lift/transfer process (for Sacramento blackfish). We found no statistical relationship between scale loss and holding time, or with the physical features of the holding and transfer environments (including debris load, wild fish density, and tank velocity). This may have been due to the variability of the physical data, the level of background scale loss, and the small number of replicates under extreme (but common) conditions.

Predation in the holding tank was very low in these experiments. A study done with juvenile Chinook salmon found increased levels of stress hormones in fish that were descaled on 10 percent or more of their body, but not an increased vulnerability to predation (Gadomski *et al.*, 1994). We do not know if descaled fish are more vulnerable to predation in the holding tanks at the TFCF but 12 fish (2 percent of all examined), including threadfin shad, Sacramento blackfish, and splittail, had scale loss > 10 percent.

Our experiments suggested that holding conditions at the TFCF were generally "fish-friendly". Morinaka's (2006) preliminary findings also suggest that holding conditions at the Skinner Delta Fish Protective Facility are fish-friendly. A newly-designed fish lift/transfer bucket scheduled for installation in 2007 at the TFCF should reduce fish injury during the transfer process. We recommend several modifications to reduce the likelihood of abrasion in the collection tank, particularly during times of high debris load or crowding from high fish density. These include partially filling the holding tank prior to collection by backfill only, using a slow drain rather than a fast drain in the removal process, reducing the amount of debris in the tank so that fish are not exposed to abrasive materials (e.g., woody vegetation, sand, clamshells) during the holding period, replacing the permanent ladder with a roll-up ladder, and determining if baffles are necessary in the tank structure (remove if no beneficial effect).

FIGURE 12.—Severe external injuries observed on some wild entrained fish, TFCF, California.

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